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IMPLEMENTATION OF THE GENERALIZED SPACE TIME AUTOREGRESSIVE (GSTAR) MODEL IN THE CASE OF THE SPREAD OF CORONAVIRUS IN THE DISTRICT CITY OF NORTH SUMATRA

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ABSTRACT

Corona Virus Disease 2019 (COVID-19) is a new virus that can be transmitted and the worst impact is death. Covid-19 first appeared in Wuhan, China and eventually spread throughout the world, one of which was North Sumatra Province. The spread of Covid-19 cases was quite rapid, until finally the World Health Organization (WHO) declared the Covid-19 case a pandemic. Based on the conditions that occurred, this final project discusses the prediction of positive cases of Covid-19 in five locations in North Sumatra using the Generalized Space Time Autoregressive (GSTAR) model. Considering that Covid-19 spreads very easily, it does not only depend on time but also the proximity between locations, so the GSTAR model is quite good to use in predicting it, assuming the parameters between locations are heterogeneous. The estimation used is OLS with inverse distance weight. This study aims to determine the best GSTAR model and forecast positive cases of Covid-19 at five locations in North Sumatra. The results show that the best GSTAR model in this study is (1_1)-OLS with an inverse weight of distance with forecasting results for the next 10 days in May 2022.

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1. INTRODUCTION

Statistics is a science in the form of a method or concept regarding planning, managing, analyzing and presenting data so as to produce a conclusion. Statistics has various explanations that can be used for all real aspects of life such as time series or data that takes a certain amount of time. In analyzing the time period, it does not only have a relationship with the conditions at the beginning but also has a relationship with the place known as data space time. The Generalized Space Time Auto Regressive (GSTAR) model is a space time model used to model and forecast time series and location data. This model produces parameters that are not necessarily the same or heterogeneous in terms of time and place. In the Generalized Space Time Auto Regressive (GSTAR) model, the effect of time is indicated by the autoregressive parameter, while the spatial effect is indicated by the location weight which states the magnitude of the relationship between locations.

In forecasting using the Generalized Space Time Autoregressive (GSTAR) model, to find out the best model for the forecast, it is necessary to calculate the Aike's information criterion (AIC) value and the root mean square error (RMSE) value, while to find out whether the forecasting results are accurate, it is necessary to calculate the value of the Mean absolute percentage error (MAPE).

The emergence of the corona virus disease 2019 (Covid-19) shocked the world in early 2020. This covid-19 virus was first discovered in Wuhan, Hubei Province, China at the end of 2019. The spread of this virus was very significant almost throughout the world, including Indonesia. On October 21, 2021 the total number of confirmed cases of contracting Covid-19 was 4,237,201 cases. Until now, most cases have occurred in DKI Jakarta, but not a few cases have spread to other provinces, one of which is North Sumatra. Based on data from the covid-19 task force, North Sumatra has 105,605 confirmed cases of contracting the covid-19 virus (covid19.go.id, 2021).

Based on data from the North Sumatra covid-19 task force on July 18 2021, the Medan City and Deli Serdang Regency areas were confirmed to be in the red zone while Binjai City, Simalungun Regency and Asahan Regency were confirmed to be in the orange or medium zone. Based on data from the Main Command Post for the North Sumatra Covid-19 Handling Task Force, there are five locations in North Sumatra with a significant increase in positive cases of Covid-19, namely Medan, Binjai, Simalungun, Deli Serdang and Asahan.

Relevant research that also uses the generalized space time autoregressive (GSTAR) model is Arum, et al (2017) with the title research for forecasting sea tides on the island of Java applying the generalized space time autoregressive (GSTAR) model with cross-correlation weights which produces a MAPE value of 11.261% and RMSE value of 13.260%.

2. RESEARCH METHODE

The research that will be used is applied research. The type of data used in this study is secondary data obtained through the daily number of positive cases of Covid-19 from 1 January 2021 to 30 April 2022. The data obtained was 485 data which were divided into two groups including training data and testing data. the use of training data is for a data model of 424 data, while the use of data testing is to check model validation of 61 data. the variables used in this study is five variables.

The steps taken to conduct this research are as follows :

a. Dividing research data into training data starting from 1 January 2021 – 28 February 2022 and data testing starting from 1 March 2022 - 30 April 2022
b. Performing descriptive statistical analysis covering time series plots, descriptive data and testing the correlation between variables
c. Perform data stationarity test in mean and variance
d. Identify the order of the gstar model by applying MACF, MPACF and AIC values
e. Calculating location weights using distance inverse location weights
f. Estimating the parameters of the GSTAR model candidates obtained with the OLS method and assistance using SAS 9.4
g. Perform an assumption test on the GSTAR model obtained to check the feasibility of the model which must meet white noise and Estimating case data for positive Covid-19 patient data training and data testing
h. Perform calculations on the smallest RMSE value to determine the best model on GSTAR
i. Make forcasting for future periods

3. RESULT AND ANALYSIS

3.1 Correlation Between Variables

Calculating the correlation between variables which aims to see the level of closeness of the relationship of each variable.

Table 1. Results of Significance Test of Correlation Coefficient Value

Correlation	$t_{statistics}$	t_{table}	Decision	Conclusion
r_{12}	35,71262	1,96488	H_0 is rejected	Significant Correlation
r_{13}	44,09528	1,96488	H_0 is rejected	Significant Correlation
r_{14}	53,10446	1,96488	H_0 is rejected	Significant Correlation
r_{15}	40,51363	1,96488	H_0 is rejected	Significant

				Correlation
r_{23}	19,62148	1,96888	H_0 is rejected	Significant Correlation
r_{24}	23,61229	1,94888	H_0 is rejected	Significant Correlation
r_{25}	26,52214	1,96488	H_0 is rejected	Significant Correlation
r_{34}	31,25281	1,96488	H_0 is rejected	Significant Correlation
r_{35}	25,07225	1,96488	H_0 is rejected	Significant Correlation
r_{45}	50,87212	1,96488	H_0 is rejected	Significant Correlation

Obtained $|t_{statistics}| > |t_{table}|$ then H_0 is rejected, so it can be concluded that there is a real correlation between the variables $Y_1(t)$ and $Y_2(t)$ in other words there is a significant correlation of positive cases of Covid-19 between Medan City and Binjai City.

3.2 Data Stationarity

3.2.1 Stationarity In Varians

Stationary in varians can be tested using the box-cox transformation. The data is said to be stationary in the varians if the resulting rounded value is 1.

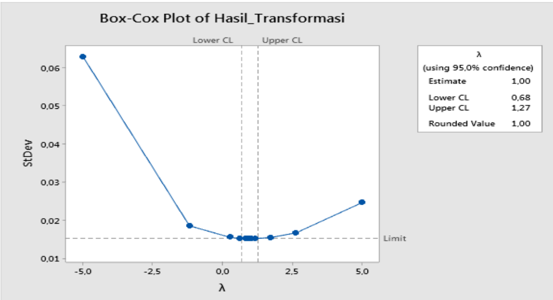

Figure 1. Result of box-cox transformation of Medan City

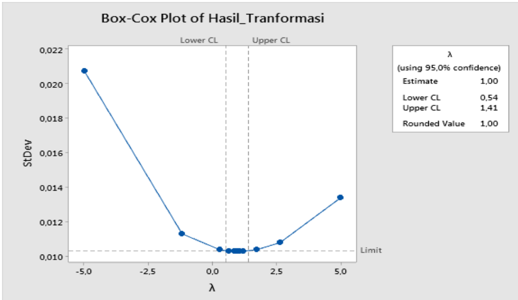

Figure 2. Result of box-cox transformation of Binjai City

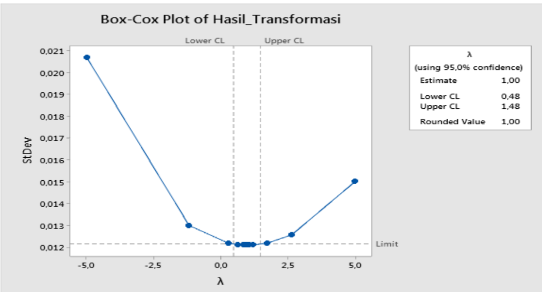

Figure 3. Result of box-cox transformation Of Simalungun Regency

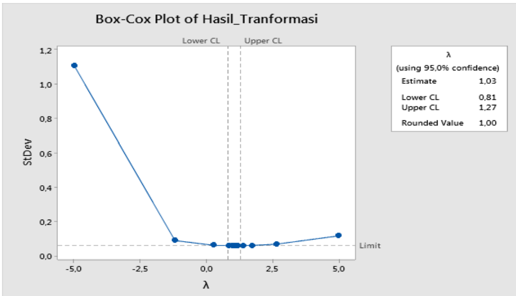

Figure 4. Result of box-cox transformation of Deli Serdang Regency

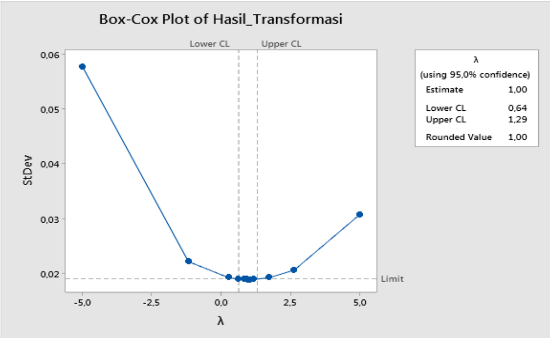

Figure 5. Result of box-cox transformation
Of Asahan regency

It can be seen in the picture that the data is stationary in the variant with a rounded value or lambda is 1.

3.2.2 Stationarity in Mean

Stationary in the mean is done using the augmented dickey fuller (ADF) test with an alpha value of 0.05

Table 2. Stationary Data Test Results After Differentencing

Variable	Probability	$t_{statistics}$	t_{table}	Decision	Conclusion
$A_1(t)$	0,0000	-4,969	-2,868	H_0 Is rejected	Stationary
$A_2(t)$	0,0000	-5,785	-2,868	H_0 Is rejected	Stationary
$A_3(t)$	0,0000	-13,073	-2,868	H_0 Is rejected	Stationary
$A_4(t)$	0,0000	-24,813	-2,868	H_0 Is rejected	Stationary
$A_5(t)$	0,0000	-3,558	-2,868	H_0 Is rejected	Stationary

The data is stationary in the mean with $|t_{statistcs}| < |t_{table}|$ so it fails to reject H_0

3.3 GSTAR Model Identification

Identification of the GSTAR model is done by looking at the MACF and MPACF plot. if the MACF scheme shows the symbol (.) dominates each lag compared to the symbols (+) and (-) then it can be said that the data is stationary.

Schematic Representation of Cross Correlations

Variable/Lag	0	1	2	3	4	5	6	7	8	9	10
Y1	+++++	+++++	+++++	+++++	+++++	+++++	+++++	+++++	+++++	+++++	+++++
Y2	+++++	+++++	+++++	+++++	+++++	+++++	+++++	+++++	+++++	+++++	+++++
Y3	+++++	+++++	+++++	+++++	+++++	+++++	+++++	+++++	+++++	+++++	+++++
Y4	+++++	+++++	+++++	+++++	+++++	+++++	+++++	+++++	+++++	+++++	+++++
Y5	+++++	+++++	+++++	+++++	+++++	+++++	+++++	+++++	+++++	+++++	+++++

+ is > 2*std error, - is < -2*std error, . is between

Figure 6. Plot MACF

Schematic Representation of Partial Cross Correlations

Variable/Lag	1	2	3	4	5	6	7	8	9	10
Y1	+....	+..-.	.....	.....	.....	.-...	.-...	.....	.....	.....
Y2	.+...	.....	.....	..-+.	.....	.....	....-	.....	.-...	.....
Y3	..+..	.....	.....	.....	.....	.....	.....	.....	.....	.....
Y4	...+.	.....	.....	.....	.....	.....	..-..	.....	.....	..-..
Y5	....+	-+.+.	+..-.	.....	+....	.....	.++.-	.....	..+..	..+..

+ is > 2*std error, - is < -2*std error, . is between

Figure 7. Plot MPACF

In this study the model formed is GSTAR with the best model based on the smallest AIC value. Then the model is obtained GSTAR (1_1).

3.4 Location Weighting

In the GSTAR model, distance inverse weights are used, which will show the relationship between two locations based on the actual distance between locations. Calculating the distance between $Y_1(t)$ and $Y_2(t)$ with equation (2.32) and equation (2.33)

$$cos(\alpha) = sin(3{,}60865)sin(3{,}61555) + cos(3{,}60865)cos(3{,}61555)\, cos(98{,}64644 - 98{,}50125)$$

$$cos(\alpha) = 0{,}9999797692349$$

$$\alpha = 0{,}9998477$$

Because the alpha angle is in degrees, it is changed as in equation (2.33).

$$d_{ij} = 6378{,}137 \times 3{,}14 \times \frac{0{,}9998477}{180} (km)$$

$$= 16{,}14046 \text{ km}$$

Calculating location weight using equation (2.31)

$$W_{12}^* = \frac{1}{W_{12}^* + W_{13}^* + W_{14}^* + W_{15}^*}$$

$$= \frac{0{,}06196}{0{,}06196 + 0{,}00913 + 0{,}02391 + 0{,}01585}$$

$$= 0{,}55895$$

Table 3. Distance Inverse Weight Calculation Results

Location		Range (km)	Weight
For	To		
$Y_1(t)$	$Y_2(t)$	16,14046	0,55895
	$Y_3(t)$	109,49037	0,08236
	$Y_4(t)$	41,83047	0,21570
	$Y_5(t)$	63,10480	0,14299
$Y_2(t)$	$Y_1(t)$	16,14046	0,57561
	$Y_3(t)$	125,13244	0,07423
	$Y_4(t)$	41,04367	0,22631
	$Y_5(t)$	74,98952	0,12384
$Y_3(t)$	$Y_1(t)$	109,49037	0,22394
	$Y_2(t)$	125,13244	0,19598
	$Y_4(t)$	116,30195	0,21094
	$Y_5(t)$	66,46544	0,36914
$Y_4(t)$	$Y_1(t)$	41,83047	0,31461
	$Y_2(t)$	41,04367	0,32053
	$Y_3(t)$	116,30195	0,11316
	$Y_5(t)$	52,28653	0,25171
$Y_5(t)$	$Y_1(t)$	63,10480	0,25016
	$Y_2(t)$	74,98952	0,21039
	$Y_3(t)$	66,46544	0,23753
	$Y_4(t)$	52,28653	0,30193

$$\mathbf{W} = \begin{bmatrix} 0 & 0{,}55895 & 0{,}08236 & 0{,}21570 & 0{,}14299 \\ 0{,}57561 & 0 & 0{,}07423 & 0{,}22631 & 0{,}12384 \\ 0{,}22394 & 0{,}19598 & 0 & 0{,}21094 & 0{,}36914 \\ 0{,}31461 & 0{,}32053 & 0{,}11316 & 0 & 0{,}25171 \\ 0{,}25016 & 0{,}21039 & 0{,}23753 & 0{,}30193 & 0 \end{bmatrix}$$

3.5 Parameter Estimation

Estimation parameter GSTAR (1_1) uses the ordinary least squares (OLS) parameter estimation method. To find out the parameter values obtained are significant or not, it is necessary to carry out a significance test using the t-test with equations (2.39) and (2.40).

T-test on parameter $\boldsymbol{\Phi}_{10}^1$

Hypothesis:

$H_0: \boldsymbol{\Phi}_{10}^1 = 0$ (parameter $\boldsymbol{\Phi}_{10}^1$ is not significant)

$H_1: \boldsymbol{\Phi}_{10}^1 \neq 0$ (parameter $\boldsymbol{\Phi}_{10}^1$ is significant)

α=5%

Test Statistics :

$t_{count}=\frac{0,97182}{0,07619}=12,75522$

$t_{table}=t_{(0,025;472)}=1,96497$

Testing Criteria:

if $|t_{hitung}|>t_{tabel}$ then H_0 is rejected so that parameter $\boldsymbol{\Phi}_{10}^{1}$ is significant to the model.

Table 4. T-test Result of GSTAR 1_1

Parameters	Estimate	Standard Error	t_{count}	t_{table}	Conclusion
$\boldsymbol{\Phi}_{10}^{1}$	0,97182	0,07619	12,75522	1,96497	Significant
$\boldsymbol{\Phi}_{11}^{1}$	0,04609	0,13094	0,35199	1,96497	Not Significant
$\boldsymbol{\Phi}_{10}^{2}$	0,84960	0,04337	19,58958	1,96497	Significant
$\boldsymbol{\Phi}_{11}^{2}$	0,02614	0,01222	2,13912	1,96497	Significant
$\boldsymbol{\Phi}_{10}^{3}$	0,56579	0,09026	6,26845	1,96497	Significant
$\boldsymbol{\Phi}_{11}^{3}$	0,22339	0,06214	3,59495	1,96497	Significant
$\boldsymbol{\Phi}_{10}^{4}$	3,22542	0,86127	3,74496	1,96497	Significant
$\boldsymbol{\Phi}_{11}^{4}$	0,44110	0,81177	0,54338	1,96497	Not Significant
$\boldsymbol{\Phi}_{10}^{5}$	-0,00251	0,01502	-0,16711	1,96497	Not Significant
$\boldsymbol{\Phi}_{11}^{5}$	1,00966	0,04779	21,12701	1,96497	Significant

So that the GSTAR (1_1) −OLS model with all parameters at each location with inverse distance weights, the model equation

$$A_1(t)=0,97182A_1(t-1)+0,02576A_2(t-1)+0,00380A_3(t-1)+0,00994A_4(t-1)+0,00659A_5(t-1)+e_1(t)$$

$$A_2(t)=0,01505A_1(t-1)+0,84960A_2(t-1)+0,00194A_3(t-1)+0,00592A_4(t-1)+0,00324A_5(t-1)+e_2(t)$$

$$A_3(t)=0,05003A_1(t-1)+0,04378A_2(t-1)+0,56579A_3(t-1)+0,04712A_4(t-1)+0,08246A_5(t-1)+e_3(t)$$

$$A_4(t)=0,13877A_1(t-1)+0,14139A_2(t-1)+0,04991A_3(t-1)+3,22542A_4(t-1)+0,11103A_5(t-1)+e_4(t)$$

$$A_5(t)=0,25258A_1(t-1)+0,21242A_2(t-1)+0,23982A_3(t-1)+0,30485A_4(t-1)-0,00251A_5(t-1)+e_5(t)$$

3.6 Testing Residual Assumptions

Residual assumption testing is carried out to check whether the alleged model is feasible and can be used for forecasting future periods, so a white noise assumption test is carried out. The white noise assumption test was carried out with the help of R-studio software with the Ljung Box test obtained p-value of 0.5795 which is greater than the alpha value of 0.05 so it can be concluded that the model meets the white noise assumption.

3.7 Forecast for May, June and July

Conduct forecasting for the months of May, June and July at five locations, namely Medan City, Binjai City, Simalungun Regency, Deli Serdang Regency and Asahan Regency using the GSTAR (1_1) −OLS models.

Table 5. Estimated Results for May, June and July 2022 After Rounding

Date	Y_1	Y_2	Y_3	Y_4	Y_5
01-Mei-22	135	6	13	25	26
02-Mei-22	132	8	18	29	22
03-Mei-22	129	9	20	29	19
04-Mei-22	126	10	21	29	17

05-Mei-22	123	10	22	28	16
06-Mei-22	121	11	21	28	15
07-Mei-22	118	11	21	27	14
08-Mei-22	115	12	21	27	14
09-Mei-22	113	12	21	26	13
10-Mei-22	110	12	20	26	13
11-Mei-22	108	12	20	25	13
12-Mei-22	105	12	19	25	12
13-Mei-22	103	12	19	24	12
14-Mei-22	101	12	19	24	12
15-Mei-22	99	12	18	23	11
16-Mei-22	97	12	18	23	11
17-Mei-22	95	12	17	22	11
18-Mei-22	92	12	17	22	10
19-Mei-22	91	12	17	22	10
20-Mei-22	89	11	16	21	10
21-Mei-22	87	11	16	21	10
22-Mei-22	85	11	16	20	10
23-Mei-22	83	11	15	20	9
24-Mei-22	81	11	15	19	9
25-Mei-22	79	10	15	19	9
26-Mei-22	78	10	14	19	9
27-Mei-22	76	10	14	18	8
28-Mei-22	75	10	14	18	8
29-Mei-22	73	10	14	17	8
30-Mei-22	71	9	13	17	8
31-Mei-22	70	9	13	17	8
01-Jun-22	68	9	13	16	8
02-Jun-22	67	9	12	16	7
03-Jun-22	65	9	12	16	7
04-Jun-22	64	9	12	15	7
05-Jun-22	63	8	12	15	7
06-Jun-22	61	8	11	15	7
07-Jun-22	60	8	11	14	7
08-Jun-22	59	8	11	14	7
09-Jun-22	58	8	11	14	6
10-Jun-22	56	8	11	14	6
11-Jun-22	55	7	10	13	6
12-Jun-22	54	7	10	13	6
13-Jun-22	53	7	10	13	6
14-Jun-22	52	7	10	12	6
15-Jun-22	51	7	9	12	6
16-Jun-22	50	7	9	12	6
17-Jun-22	48	7	9	12	5
18-Jun-22	47	6	9	11	5

19-Jun-22	46	6	9	11	5
20-Jun-22	45	6	9	11	5
21-Jun-22	44	6	8	11	5
22-Jun-22	44	6	8	11	5
23-Jun-22	43	6	8	10	5
24-Jun-22	42	6	8	10	5
25-Jun-22	41	6	8	10	5
26-Jun-22	40	5	7	10	4
27-Jun-22	39	5	7	9	4
28-Jun-22	38	5	7	9	4
29-Jun-22	37	5	7	9	4
30-Jun-22	37	5	7	9	4
01-Jul-22	36	5	7	9	4
02-Jul-22	35	5	7	9	4
03-Jul-22	34	5	6	8	4
04-Jul-22	34	5	6	8	4
05-Jul-22	33	4	6	8	4
06-Jul-22	32	4	6	8	4
07-Jul-22	32	4	6	8	4
08-Jul-22	31	4	6	7	3
09-Jul-22	30	4	6	7	3
10-Jul-22	30	4	6	7	3
11-Jul-22	29	4	5	7	3
12-Jul-22	28	4	5	7	3
13-Jul-22	28	4	5	7	3
14-Jul-22	27	4	5	7	3
15-Jul-22	27	4	5	6	3
16-Jul-22	26	4	5	6	3
17-Jul-22	25	3	5	6	3
18-Jul-22	25	3	5	6	3
19-Jul-22	24	3	5	6	3
20-Jul-22	24	3	5	6	3
21-Jul-22	23	3	4	6	3
22-Jul-22	23	3	4	6	3
23-Jul-22	22	3	4	5	3
24-Jul-22	22	3	4	5	2
25-Jul-22	21	3	4	5	2
26-Jul-22	21	3	4	5	2
27-Jul-22	20	3	4	5	2
28-Jul-22	20	3	4	5	2
29-Jul-22	20	3	4	5	2
30-Jul-22	19	3	4	5	2
31-Jul-22	19	3	4	5	2

Calculating the best forecasting results at each location by calculating the mean absolute percentage error (MAPE) with equation (2.43).

$$\text{MAPE } Y_1(t) = \left(\frac{\sum_{t=1}^{n}|Y_t - \bar{Y}_t|}{Y_t}\right).100$$
$$= \frac{3{,}33}{92}.100$$
$$= 3{,}62\%$$

The MAPE results for Medan City were 3.62%, Binjai City were 2.45%, Simalungun Regency were 2.82%, Deli Serdang Regency were 27.37% and Asahan Regency were 10.26%. where for Medan City, Binjai City, Simalungun Regency have very good forecasting abilities while for Deli Serdang Regency and Asahan Regency have good forecasting abilities.

4. CONCLUSION

The best GSTAR model that is suitable for predicting positive COVID-19 case data in Medan City, Binjai City, Simalungun Regency, Deli Serdang Regency and Asahan Regency is the GSTAR (1_1) −OLS model with inverse distance weights, and forecasting results for May, June and July with a MAPE of Medan City were 3.62%, Binjai City were 2.45%, Simalungun Regency were 2.82%, Deli Serdang Regency were 27.37% and Asahan Regency were 10.26%. The results of forecasting the positive number of Covid-19 in five locations for May, June and July 2022, the highest cases in Medan city were 135 cases, the highest cases in Binjai city were 12 cases, in Simalungun district the highest cases were 21 cases, in Deli Serdang district as many as 29 cases and Asahan district as many as 26 cases.

REFERENCES

[1] Arum, C. W., Abdul,. H & Rita. R. (2016). Peramalan Pasang Surut Air Laut Di Pulau Jawa Menggunakan Model Generalized Space Time Autoregressive (GSTAR). *Jurnal Gaussian*, 5(4), 623-632

[2] Faizah, L.A.& Setiawan. (2013). Pemodelan Inflasi di Kota Semarang, Yogyakarta dan Surakarta dengan Pendekatan GSTAR. *Jurnal Sains dan Seni Pomits*, 2(2)

[3] Gurajati, D. (2006). *Ekonometrika Dasar*. Jakarta: Erlangga.

[4] Hardiyanti, S. A., & Shofiyah., Q. (2020). Prediksi Kasus Covid-19 Di Indonesia Menggunakan Metode Adaptive Neuro Fuzzy Inference System (ANFIS). *Seminar Nasional Terapan Riset Inovatif (SENTRINOV)* Vol. 6, No. 1.

[5] Heizer, Jay & Barry Render. (2015). *Manajemen Operasi, Manajemen keberlangsungan dan Rantai Pasokan*. Jakarta: Salemba Empat.

[6] Islamiyah, A. N., Rahayu, W., danWiraningsih, E. D. (2018). Penerapan Model Generalized Space Time Autoregressive (GSTAR) Terhadap Penderita TB Paru (BTA+) di DKI Jakarta. *Jurnal Statistika Dan Aplikasinya*, 2(2), 36 - 48.

[7] Nida, F.A., Sri, S.H.,& Etik. Z. (2020). Penerapan Model Generalized Space Time Autoregressive (GSTAR) Pada Data Nilai Tukar Petani 3 Provinsi di Pulau Sumatera. *Jurnal Seminar Nasional Pendidikan Matematika*, 1(1), 209-220

[8] Nur, A. I,. Widyanti, R & Eti, D,.W. (2018). Pemodelan Generalized Space Time Autoregressive (GSTAR) dan Penerapannya Pada Penderita TB Paru (BTA+) di DKI Jakarta. *Jurnal Statistika dan Aplikasinya*, 2(2), 36-48

[9] Nugroho, S., Akbar, S., & Vusvitasari, R. (2015). *Kajian Kaitan Koefisien Korelasi Pearson (r), Spearman-Rho* (ρ)*, Kendall-Tau* (τ)*, Gamma (G), Serta Somers* (Dyx)*. Jurnal Gradien Vol. 4 No.2.*

[10] Sanusi, W., Maya,. S,. W & Rahmat. S. (2018). *Model Space Time Autoregressive (STAR) dan Aplikasinya Terhadap Penyakit Demam Berdarah Dengue di Provinsi Sulawesi Barat. Journal Of Mathematics*, 1(2), 115-124

[11] Sarwono. J. (2006). *Metode Penelitian Kuantitatif Dan Kualitatif*. Yogyakarta: Graha Ilmu

[12] Serly, Novita Laamena. (2017). Pendekatan Model Generalized Space Time Autoregressive (GSTAR) Untuk Pemodelan Data Gempa. *Prosiding Seminar Nasional Inovasi Teknologi*, 50-60

[13] Setiya, S.N. (2019). *Generalized Space-Time Autoregressive (GSTAR)* (Studi Kasus Peramalan Harga Saham Syariah Empat Perusahaan di JII). *Faktor M Journal*, 2(1), 39-50

[14] Suhartono dan Atok, R.M. (2006). Pembobot Lokasi Secara Optimum Dipilih Terhadap model GSTAR. *Presented at National Mathematics Conference XIII*.Semarang: UniversitasNegeri Semarang.

[15] Wutsqa, D.U, Suhartono & Sujito, B. (2010). *Generalized Space Time Autoregressive Modelling. Proceedings Of The 6th IMT-GT Conference on Mathematics, Statistic and Its Apllication* (ICMSA2010). Kuala Lumpur Malaysia: Universitas Tuanku Abdul Rahman.